The Application of Mathematical Morphology and Sobel Operator in Infrared Image Edge Detection

Xiaokang Zhang[1, a], Runping Han[2, b]

[1]School of Information and Engineering, Beijing Institute of Fashion Technology, Beijing, 100029, China

[2]School of Information and Engineering, Beijing Institute of Fashion Technology, Beijing, 100029, China

[a]email: zhxk163@163.com, [b]email:gxyhrp@bift.edu.cn

Keywords: Infrared Image; Edge Detection; Mathematical Morphology; Sobel Operator

Abstract. The paper studies the edge detection of infrared image. Aiming at the disadvantage of the low contrast and the fuzzy edge in infrared image, a new algorithm of infrared image edge detection based on mathematical morphology and Sobel operator is proposed. Firstly, it uses four operations of mathematical morphology with different types of structure elements to detect infrared image edge. Then, the useful details of the infrared image can be obtained and the binary image will be got after the infrared image being processed with the four operations. Finally, infrared image edge can be detected by sharping and thinning the binary image that contains the details with Sobel operator. The result shows that the algorithm presented in the paper can effectively detect the infrared image's edge information compared with the traditional edge detection algorithms. It is proved to be practical and feasible.

I Introduction

Infrared image is the visual image that indicates the temperature distribution of surrounding objects by the detection and processing of electromagnetic wave that comes from the objects in the nature with the infrared thermal imager. With the development of infrared technology, infrared imaging system is more and more widely used in aerospace, remote sensing, industry, medicine, fire protection, military and so on. Due to the low contrast, the fuzzy edge, and the serious noise in infrared image, the infrared image need to be processed to achieve the ideal application level. Image edge generally refers to the set of pixels that has step or roof shape changes, which exists between target and background, target and target, region and region and so on [1]. Edge detection has a very important role in the image preprocessing, and its application is also very extensive in the aspects such as image processing and intelligent identification. Therefore, the edge extraction of the target in infrared image is also an important step for image processing.

At present, the classical edge detection operators include Roberts, Prewitt, Sobel, Gauss of Laplacian, Canny operator and so on[1][3]. And Roberts operator uses the partial differences to detect the edge with the higher positioning accuracy, but it doesn't have the ability to suppress noise; Prewitt and Sobel operators can use the neighborhood information to detect the edge so that they have certain inhibition of noise, but the detection result has the false edge; since Gauss of Laplacian operator is a second derivative one, it's sensitive to noise; Canny operator's edge detection is more effective, but it is easy to produce double pixel boundary and it is sensitive to noise. At the same time, in consideration of the imaging mechanism, imaging system characteristic of infrared thermal imager and the diversity of image display, the commonly edge detection algorithms have some limitation to be applied directly to infrared image. According to the characteristics of infrared image, this paper presents a method that collects infrared image edge details with mathematical morphology [1][2] and detects and thins the image edge with Sobel operator and finally infrared image edge can be extracted effectively.

II The Principle of Mathematical Morphology

2.1 The Basic Morphological Operation

Mathematical morphology is a discipline that is based on strict mathematical theory, which is a kind of nonlinear filtering method. It is a mathematical tool of image analysis that is based on morphological structure element. The basic idea is to use certain forms of structural elements to measure and extract the corresponding shape from the image for accomplishing the image analysis and recognition. Mathematical morphology includes the basic operations of erosion，dilation, opening and closing [4].

(1) Erosion operation can reduce or even eliminate the bright area that is less than the structural element, which can effectively remove the isolated noise points and the protruding parts of the boundary. Dilation operation is the process of incorporating all the background points that contact with the object into the object, which can fill the empty and form a connected domain and smooth the concave parts of the image's boundary.

Erosion operation is defined as the following:

$$A\Theta B(\mathrm{x},\mathrm{y}) = \min\{B(\mathrm{x}+\mathrm{s},\mathrm{y}+t) - B(\mathrm{s},\mathrm{t})\} \quad (1)$$

Dilation operation is defined as the following:

$$A\oplus B(\mathrm{x},\mathrm{y}) = \max\{A(\mathrm{x}-\mathrm{s},\mathrm{y}-\mathrm{t}) - B(\mathrm{s},\mathrm{t})\} \quad (2)$$

Among them, A (x, y) represents gray image, B (s, t) represents structural element.

(2) Opening operation means the image will be firstly processed by the erosion operation and then be processed by the dilation operation which can remove the isolated area and the burr of the image and the shape peak that is less than structural element will be also eliminated. Closing operation means the image will be firstly processed by the dilation operation and then be processed by the erosion operation, which is mainly used to fill small holes inside the object, connect the boundary of the near object and smooth the object.

Opening operation is defined as the following:

$$A \circ B = (A\Theta B) \oplus B \quad (3)$$

Closing operation is defined as the following:

$$A \bullet B = (A \oplus B)\Theta B \quad (4)$$

Among them, Θ represents the erosion operation and ⊕ represents the dilation operation.

2.2 Structural Element

Structural element is one of the most important and most basic concepts in the morphological image processing. It is a kind of probe to collect image information in the image analysis. By observing the moving probe in the image, the relation of various parts can be revealed to obtain the useful information of the image.

Choosing different structural element can obtain the processed result of different geometry information. Structural element at the same time also determines the amount of data transformation. In general, the size and shape of structural element will affect the result of the image edge detection. Small structural element's denoising ability is weak, but it can detect the edge details, large structural element's denoising ability is strong, but the detected edge is coarser.

Therefore, different structure element has different image edge detection ability. Usually two principles should be considered about the choice of structural element: one is structural element must be simpler and be bounded; the other is structural element should have some convexity such as round, square and cross[5]. (As shown in the following).

$$\begin{matrix} & & 1 & & \\ & 1 & 1 & 1 & \\ 1 & 1 & 1 & 1 & 1 \\ & 1 & 1 & 1 & \\ & & 1 & & \end{matrix}$$

(a) Round

$$\begin{matrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{matrix}$$

(b) Square

$$\begin{matrix} & 1 & \\ 1 & 1 & 1 \\ & 1 & \end{matrix}$$

(c) Cross

III Sobel Operator

As we all know, Sobel operator is a gradient operator and it is mainly used to detect the digital image's edge. Sobel operator has two basic operators with the horizontal direction and the vertical direction as the following:

$$f_x: \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \qquad f_y: \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}$$

Therefore, the gradient amplitude is $F(\mathrm{x},\mathrm{y}) = \sqrt{f_x^2 + f_y^2}$ and its approximation is $F(\mathrm{x},\mathrm{y}) = |f_x| + |f_y|$ for calculating easily. Appropriate threshold τ can be selected to judge the pixel points while using the Sobel operator. Among the pixel points in infrared image, if the pixel's amplitude F (x, y) > τ, the point (x, y) will get the value of the pixel point, otherwise the point(x,y) is 0. The set of the obtained pixel points is the binary image of the edge detection.

IV Concrete Algorithm and Result Analysis

4.1 The Theory of Morphological Edge Detection

On the basis of erosion operation, dilation operation, opening operation and closing operation, three common edge detection operators can be obtained. Their mathematical definitions are as the following:

The edge detection operator with the dilation structure is as the following:

$$E_d(\mathrm{x},\mathrm{y}) = (f \oplus b)(\mathrm{x},\mathrm{y}) - f(\mathrm{x},\mathrm{y}) \tag{5}$$

The edge detection operator with the erosion structure is as the following:

$$E_e(\mathrm{x},\mathrm{y}) = f(\mathrm{x},\mathrm{y}) - (f \Theta b)(\mathrm{x},\mathrm{y}) \tag{6}$$

The edge detection operator with the dilation structure and the erosion structure (also called morphological gradient operator) is as the following:

$$G(\mathrm{x},\mathrm{y}) = (f \oplus b)(\mathrm{x},\mathrm{y}) - (f \Theta b)(\mathrm{x},\mathrm{y}) \tag{7}$$

The three operators above can respectively extract the inward flange, the external rim and the edge information of crossing on the actual Euclidean border, but they are all very sensitive to noise. And they can be used to detect the image with little noise.

Aiming at the shortcomings of the above common operators, the morphological edge detection algorithm based on multi-scale and multi-structuring elements is offered. Its mathematical definition is as the following:

$$\begin{cases} F(\mathrm{x},\mathrm{y}) = 0.5 f_M(\mathrm{x},\mathrm{y}) + 0.5 f_N(\mathrm{x},\mathrm{y}) \\ f_M(\mathrm{x},\mathrm{y}) = \sum_{i=1}^{4} a_i f_i(\mathrm{x},\mathrm{y}) \\ f_N(\mathrm{x},\mathrm{y}) = \sum_{i=1}^{3} a_i f_i(\mathrm{x},\mathrm{y}) \end{cases} \tag{8}$$

Among them, $f_M(\mathrm{x},\mathrm{y})$ is used to describe the edge detection result of multi-structuring element, $f_N(\mathrm{x},\mathrm{y})$ is used to describe the edge detection result of multi-scale element, and a_i is used to describe the weighting coefficient. However, because of the large amount of calculation, the algorithm is not widely used in gray image.

Likewise, in order to obtain more edge details and suppress the noise of the infrared image, this paper presents a morphological edge detection operator based on double structure and double scale elements. Its mathematical definition is as the following:

$$E(I) = (I \circ B) \oplus A - (I \bullet B) \Theta A \tag{9}$$

Among them, A is the 5 * 5 circular structural element for removing the noise, B is the 3 * 3 square structural element for extracting the image edge details and I is an infrared image.

$$A = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

4.2 The Concrete Algorithm

Flow chart of the algorithm is shown in figure1:

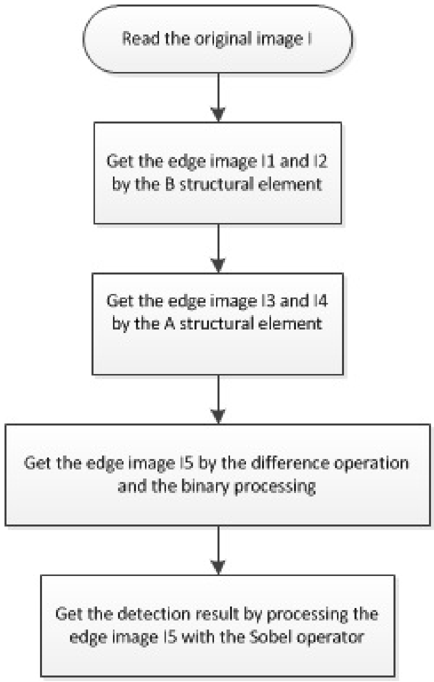


Figure1 Flow chart

The specific steps are as the following:

(1) Firstly, the original infrared image I should be read.

(2) According to the formula (9), the original image I will be respectively processed by the opening operation and the closing operation based on the B structural element for getting image I1 and I2.

(3) Then, the image of I1 and I2 will be respectively processed by the dilation operation and the erosion operation based on the A structural element for getting image I3 and I4.

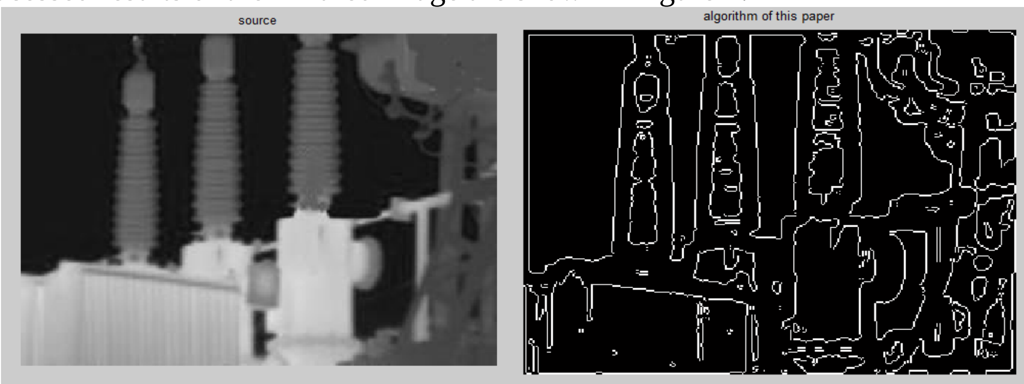
(4) The result will be got by letting the image I3 minus the image I4 and the image I5 will be got by the binary processing of the result.

(5) At last, the result of the edge detection will be got by processing and thinning the image I5 with the Sobel operator.

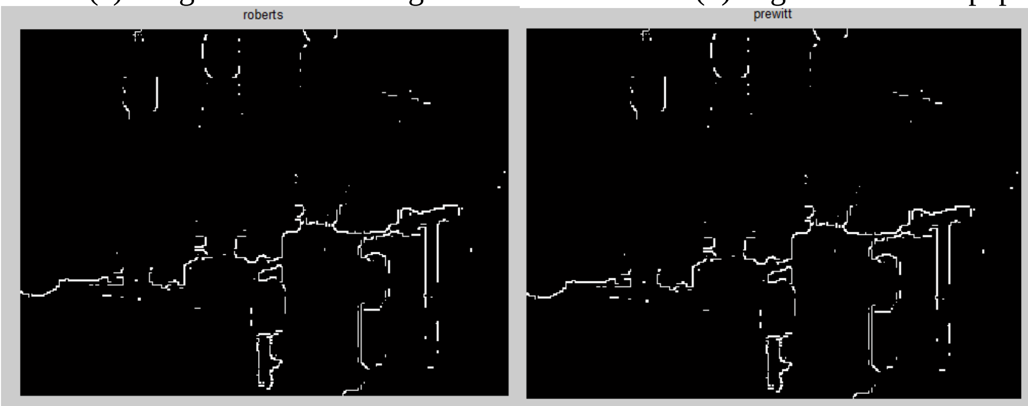
4.3 The Experimental Results and Analysis

In order to discuss the feasibility and the effectiveness of the algorithm in this paper, the 320 x 240 infrared image will be processed in the paper using the algorithm of the paper and the traditional operators. We will select the threshold $\delta = 0.05$ for the binaryzation in the experiment.

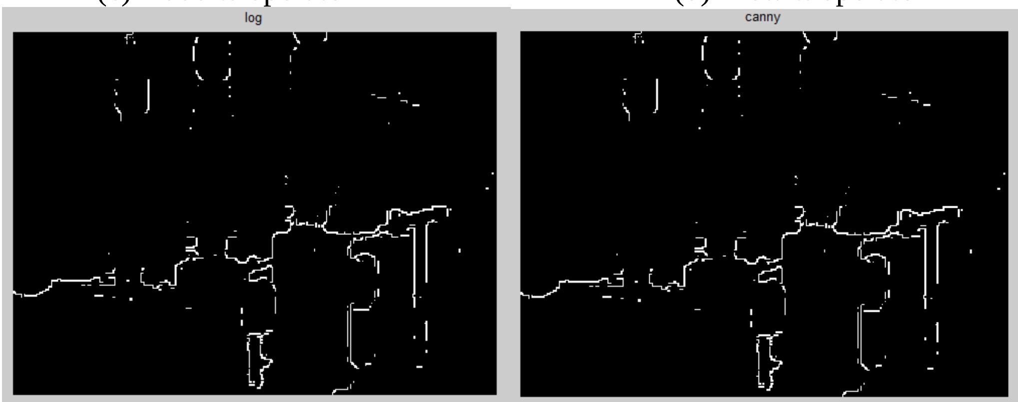
The processed results of the infrared image are shown in figure 2:



(a) Original infrared image (b) Algorithm of this paper



(c) Roberts operator (d) Prewitt operator



(e) Gauss-Laplacian operator (f) Canny operator

Figure 2 The result of edge detection

Just as shown, (a) is the original infrared image; (b) is the edge detection result after being processed by the algorithm of this paper; (c) - (f), respectively, are the edge detection results after being processed by the corresponding operators of Roberts, Prewitt, Gauss-Laplacian and Canny. Clearly, the edge detection results by the traditional operators contain less image edge information and they are difficult to express the characteristics of the infrared image. While the edge detection result by the algorithm of this paper gets more effective edge details.

V Conclusion

Image edge detection is an important research direction in the image processing and it has much influence on the later image analysis. The analysis of the experimental results illustrates that using the traditional gradient operators directly to process the infrared image has great limitation. But more edge information of the infrared image can be obtained by the algorithm of this paper effectively, which verifies the effectiveness of the algorithm.

Acknowledgement

The authors acknowledge the financial support of Beijing Municipal Education Commission under Grant No.KM201310012002.

References

[1] Wang Dongxia, Xuweichang. Algorithm Research of Edge Detection based on the Improved Mathematical Morphology[J]. Laboratory Research and Exploration, 2014, 33(2): 89-92.

[2] Huang Jianling, Zhou Hui. A Image Edge Detection Method of Multiple Structure and Multi-scale Elements based on Morphology[J]. MICROELECTROICS & COMPUTER, 2009, 26(8):76-79.

[3] Wang Kangtai, Dai Wenzhan. A Kind of Image Edge Detection based on Sobel Operator and the Grey Correlation Method[J]. Computer Applications. 2006, 26(5): 1035-1047.

[4] Huang Hailong, Wang Hong, Ji Li. Order Morphological Edge Detection Algorithm based on Local Fuzzy Enhancement[J]. Chinese Journal of Science Instrument. 2012, 33(11): 2608-2614.

[5] Duan Ruiling, Li Qingxiang, Li Heyu. Reviewed Research of Image Edge Detection Method[J]. OPTICAL TECHNIQUE. 2005, 31(3): 415-419.